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EVALUATION OF NON-ILLUMINATED GUIDE SIGNS

State of the Art

Final Report

Prepared by:
Jonathan E. Upchurch
Center for Advanced Research in Transportation
College of Engineering & Applied Sciences
Arizona State University
Tempe, Arizona 85287

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16. ABSTRACT

The report presents an evaluation of non-illuminated guide signs. The objective of this study was to prepare a state-of-the-art report and develop a research work plan for any recommended further research. The study has reviewed research conducted by others and current practice and any standards used in installation of non-illuminated guide signs.

The state-of-the-art report assumed that MUTCD standards which require freeway overhead guide signs to be either illuminated or have reflectorized backgrounds will continue. The general consensus on the findings developed from the previous work can be stated as follows: For typical, uncomplicated freeway application, the legend background treatments in common use can all give satisfactory legibility. A possible exception is the marginal legibility of non-illuminated signs viewed under the lowbeam illumination of a single vehicle. Auxiliary illumination may be required on curved roads, at locations where adverse weather is prevalent, under conditions of high ambient illumination, and at sites where immediate action by the driver is required. Studies have also shown that motorists prefer illuminated signs and signs with reflective backgrounds over opaque backgrounds.

Previous research also strongly suggests that non-illuminated, reflectorized background treatments can be economically competetive with or less expensive than illuminated systems. It is therefore recommended that further research be done to compare the cost of different sign treatments and should include cost analysis for retrofitting existing opaque sign panels with reflectorized background.

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INTRODUCTION

This report presents an evaluation of Non-Illuminated Guide Signs. The report was prepared in response to a September 15, 1986 request by the Arizona Department of Transportation. Shown below are the Problem Statement for this projet and the Research Objectives to be achieved in developing this state-of-the-art-report.

Problem Statement:

In a recent research project, it was found that, compared to illuminated signs, one non-illuminated reflectorized background sign performed very well in an observer study. Based on recent research studies, a number of states have decided to use reflectorized backgrounds in lieu of illumination of many of their overhead signs. Recent research suggests that reflectorized systems offer satisfactory performance for legibility. Advantages of non-illuminated signs include no annual power cost and improved worker safety due to greatly reduced maintenance needs.

Research Objectives:

The objective of this study is to prepare a state-of-the-art report and develop a research work plan for any recommended research.

The following tasks will be performed:

1. Review operational and research studies conducted by others. This review will determine the performance of reflectorized systems.
2. Review the current practice and any standards used in installation of non-illuminated guide signs.

3. Provide a recommendation for further research which would determine application and provide guidelines for use of non-illuminated, reflectorized guide signs.
4. Develop a detailed work plan for any recommended research, and establish the anticipated project duration and estimated budget.
5. Prepare a state-of-the-art report summarizing the results of the previous tasks.

This state-of-the-art report assumes that MUTCD standards which require freeway overhead guide signs to be either illuminated or have reflectorized backgrounds will continue. Although one state (California) has proposed that non-illuminated, opaque background signs be permitted, it does not appear that this change will occur in the near future.

The subject of sign treatments has taken on a new importance during the past year. As a result of strong public support a funding program is now in place to construct 231 additional miles of freeway in the Phoenix urban area in the next 20 years. A large number of overhead signs will be installed on this new mileage. The existing Phoenix area freeway system has a average of 8.1 overhead signs per mile of freeway. At this density there will be 1871 new overhead signs installed on 231 miles of freeway projected to be built in the next 20 years. Even if sign density is reduced by 50 percent, nearly 1000 new overhead signs may be installed. If a more economical sign treatment (i.e., non-illumination) can be used, then monies will be more wisely spent as Arizona constructs and begins to operate the new freeway mileage.

A second reason for the new importance of sign treatments is the new legislation requiring sign lighting systems to be mounted overhead. The

overhead mount may require additional expense for initial installation and will require additional cost for routine maintenance. If a non-illuminated system could be employed, initial installation and routine maintenance costs could be avoided. In addition, the concerns of the astronomical community about light pollution from sign lighting systems would be greatly reduced.

Definitions

Five terms are used in this report to describe materials used for sign legend and background. They are defined below.

Opaque - This material has virtually no reflecetive properties. In Arizona a procelain enamel is used as an opaque background on most overhead signs.

Engineering Grade Reflective Sheeting - Also commonly referred to as Type II Sheeting. This material has good reflective properties. Also known as Enclosed Lens Reflective Sheeting.

High Intensity Reflective Sheeting - Also commonly referred to as Type III Sheeting. This material has much higher reflective properties than Engineering Grade. Also known as Encapsulated Lens Reflective Sheeting.

Super Engineering Grade Reflective Sheeting - This material has reflective properties higher than Engineering Grade but less than High Intensity. Also known as Premium Engineering Grade.

Reflector Buttons - These circular dots are made up of corner-cube retro-reflectors. They are often used for the legend and border on overhead signs. In Arizona they are overlaid on a white porcelain enamel letter or border.

REVIEW OF STUDIES CONDUCTED BY OTHERS

FACTORS TO CONSIDER IN SELECTING TYPE OF SIGN TREATMENT

Several factors are usually considered in selecting the type of sign treatment (illuminated versus non-illuminated and selection of sign materials). These factors can be broadly classified into two categories: 1) Performance of the treatment (how well it serves the needs of the motorist; and 2) Economic considerations

Performance can be evaluated in terms of conspicuity provided by the sign and the legibility distance that it provides. Although the body of literature is not unanimous, it tends to suggest that illuminated signs perform better than signs with reflective backgrounds and signs with reflective backgrounds tend to perform better than signs with opaque backgrounds.

Economic considerations incorporate many factors. In general, the economic order of preference for sign treatments is opposite the order of performance noted above. Specific factors are listed below.

1. Initial installation costs. These costs tend to be higher for illuminated systems due to light fixtures and long service connections to power sources (especially in rural areas). Additional structural supports are required for fixture mounting and for catwalks that usually not installed on non-illuminated signs.
2. Maintenance costs. Maintenance is a regular and continuing process for illuminated signs. Routine maintenance includes washing and relamping of fixtures and replacement of damaged and worn out lighting and signing materials. Periodic night inspections are required to locate malfunctioning lights. Repairs

to overhead sign lighting can require lane closures involving traffic control devices, light maintenance trucks and personnel, and in certain locations, the aid of state police. Maintenance activities of this type result in motorist inconvenience. Workers and motorists safety is an issue.

3. Energy costs. The cost of electric power to maintain sign illumination is significant.
4. System life. The lifetime of various treatments varies considerably. The service life of ballasts and electrical components varies. Signing materials of different types differ in durability.

Available treatments and materials differ widely in initial cost, durability, and maintenance problems. Each of these factors is pertinent to a cost-effective analysis.

WHAT PERFORMANCE DOES THE MOTORIST NEED?

A key question to be answered when evaluating illuminated systems versus non-illuminated systems is "What level of performance does the motorist need?" Depending on how this question is answered it is possible that:

1) both illuminated and non-illuminated systems offer adequate performance; or
2) only one type of system offers adequate performance; or
3) despite widespread usage of both, neither system offers adequate performance.

To perform adequately, a guide sign must accomplish two things. First, it must be detected by the motorist and the sign must have enough legibility distance so that the motorist can read the sign message before he drives

past the sign. Second, the sign must be placed far enough in advance of an exit ramp (or other change in vehicle path) so that the driver can make a decision and maneuver to use the exit ramp (or other path) before he arrives at that point. This concept is described in more detail in the Decision Sight Distance Model developed by Hugh McGee in the mid-1970's.

Presumably, the longitudinal locations of guide signs along the roadway are selected so that there is an adequate distance for the driver to make a decision and maneuver after passing the sign. The critical element then becomes "How much legibility distance is required?" A 1977 study by the New York State Department of Transportation defined "adequate legibility distance" as that distance providing a driver enough time to read a sign at his travel speed. These researchers determined that eight words would be read in 5.33 seconds, which requires 394 feet at 55 mph or 469 feet at 60 mph. Another oft-quoted formula for reading time is (N/3)+2 seconds, (Moore and Christie-1963), where N equals the number of words on the sign (6). This empirical approach would provide 4.67 seconds for reading an 8-word sign. At 55 mph this corresponds to 377 feet.

If a sign is located close to a maneuver point, it may be advisable to have greater legibility distance than these formulas provide.

LEGIBILITY

One of the most important questions about non-illuminated versus illuminated signs is "How does their performance compare in terms of legibility distance?" Several studies have been done in an attempt to answer this question. One major laboratory study has been conducted. Other studies have been field oriented. This section of the report describes the findings of these studies.

Olson and Bernstein (6) conducted a laboratory study to define the relationship between sign luminance and legibility in a way that would assist in selecting optimum materials for signing applications. The authors pointed out that a multitude of factors influence the luminance of retroreflective signs (see Table 1). A laboratory study can fix many of these factors so that they do not vary during an experimental procedure. A field study, on the other hand, cannot exercise as much control over all of these factors and hence, the results of field studies may be more variable. A discussion of field-oriented studies later in this section will demonstrate some variation in results.

Figure 1 illustrates some of the major findings of the Olson and Bernstein study. Legibility Distance (the distance from which a sign can be read) is expressed in terms of the number of feet per inch of letter height. For example, if the legibility distance is 50 feet per inch of letter height, then a ten inch letter can be read from a distance of 500 feet. The study found that legibility distance is a function of the brightness (specific luminance) of the legend and the brightness of the background. To understand the meaning of Figure 1 it is helpful to know the specific luminance of materials commonly used for sign treatments. They are listed below.

TABLE 1. LISTING OF VARIABLES SIGNIFICANTLY INFLUENCING THE LUMINANCE OF RETROREFLECTIVE SIGNS

Number	Source	Description
1	Sign	Background Reflectivity
2	Sign	Legend Reflectivity
3	Sign	Background Color
4	Sign	Placement (vertical and horizontal) relative to the roadway
5	Environment	Luminance of the environment within which the sign is place (surround luminance)
6	Environment	Road alignment in the approach to the sign
7	Car	Headlight characteristics (photometry and aim) of the vehicle providing the illuminance
8	Car	Position of the car on the road (lane position and distance from the sign)
9	Observer	Observer visual characteristics

Source: Reference 6

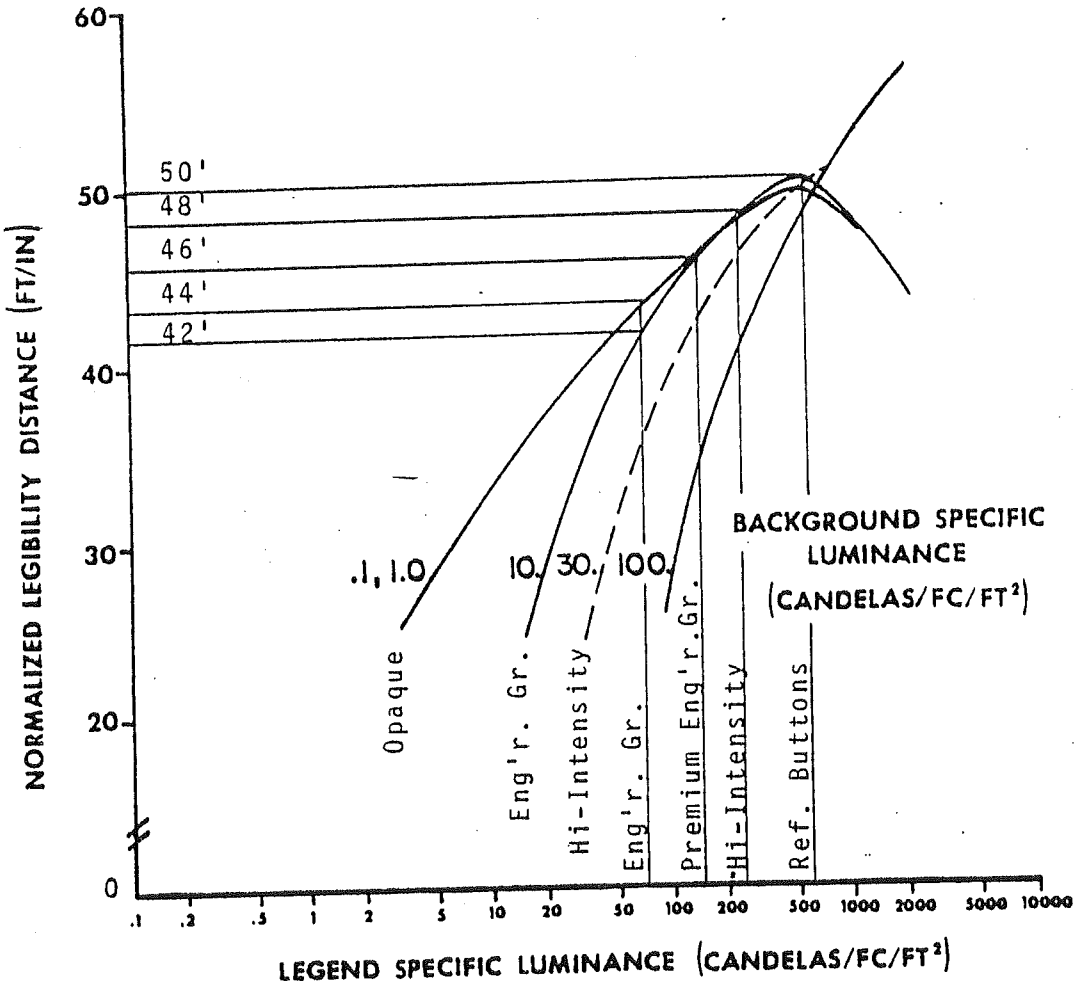

Figure 1. LEGIBILITY DISTANCE FOR AN OVERHEAD SIGN; LOW BEAMS; LEGEND 20 FT. ABOVE PAVEMENT AND CENTERED OVER DRIVER'S LANE

Source: Reference 9

Material	Specific Luminance (candelas/fc/ft^2)	
	Green	White
Opaque (non-reflective)	0.1 - 1.0	0.1 - 1.0
Engineering Grade (Type II reflective sheeting)	15	100
Super-Engineering Grade	28 - 30	150 - 160
"Hi-Intensity" (Type III) reflective sheeting	45 - 65	250 - 340
Reflector buttons	---	600 (equivalent to a reflectorized sheeting of 600)

As shown in Figure 1, reflector buttons on a Type III (Hi-Intensity) background would yield a legibility distance of 50 feet per inch. As a second example, a Type II (Engineering Grade) legend on an Engineering Grade background would provide 42 feet per inch in legibility distance. Figure 1 is based upon a non-illuminated overhead sign centered over the driver's lane and with a legend 20 feet above the pavement. Futhermore, the sign is being illuminated by the headlights of one car with low beams. In comparison to the legibility distances of 50 and 42 feet per inch, an illuminated sign would have legibility distance of about 60 feet per inch. Thus, in terms of legibility distance, an illuminated sign performs somewhat better than a non-illuminated sign for the very specific conditions in this example. The performance of non-illuminated system can improve with: use of high beams; presence of stream traffic (several vehicles illuminating the sign simultaneously can increase sign luminance by a factor of eight (reference 15)); and when the pavement is wet (headlight illumination is reflected off of the pavement and up to the sign).

Additional findings and conclusions of the Olson and Bernstein study are quoted below.

"The results of the project indicate that any sign background material in use today, or likely to be available in the near future, can provide satisfactory legibility. Highly reflective materials have the potential (depending on the choice of legend material) of providing somewhat greater legibility distance than others, but the difference is not great (about 10%, comparing highly reflective and non-reflective options). Perhaps of greater consequence is the fact that the legibility characteristics of non-reflective and low-reflective background signs change a great deal more, depending on the headlamp beam being used or the amount of stream traffic, than do the legibility characteristics of moderately and highly reflective signs. For example, if two signs were placed side by side, one having a non-reflective and the other a highly reflective background, their legibility distances would probably not differ by more than 10% when viewed under design conditions (e.g., isolated car, low beams)."

"The use of highly reflective background materials makes possible somewhat greater legibility distance and allows the maximum to be maintained through a greater range of viewing conditions (e.g., high and low beams and changes in traffic density.) As the reflectivity of the background material is decreased, the maximum potential legibility distance decreases somewhat and the range of viewing conditions associated with maximum legibility is also decreased. Thus, whether the sign is viewed with high or low beams, for example, can have a substantial

effect in terms of legibility distance with non-reflective or low-reflective background materials (unless the sign is illuminated)."

"While highly reflective sign backgrounds have the potential of providing somewhat greater legibility distance than non-reflective or moderately reflective backgrounds, any background material is capable of yielding satisfactory legibility distance. The primary differences among backgrounds are in terms of conspicuity, color rendition and ability to maintain maximum legibility distance under a variety of illumination conditions."

"In sum, sign backgrounds have a substantial effect on sign legibility and the choice is an important one to a traffic engineering agency. From a legibility point of view, reflectorized backgrounds are favored. Whether the moderate legibility advantages associated with highly reflective background materials are cost-beneficial requires consideration of other factors such as purchase price, effective life, etc."

"Increasing background luminance results in some improvements in peak legibility potential of the sign. However, the legibility actually achieved depends largely on the legend luminance."

"The luminance of the environment within which a sign is placed also has an effect on legibility. Barring the presence of glare sources near the sign, higher surround luminance improves legibility and reduces the effects of excessive legend luminance. Thus, the same sign could be read at a greater distance if placed in a highly illuminated urban environment rather than in a dark rural environment."

Field studies have focused on comparing different types of signing treatments in field settings. These studies will be reviewed here in the chronological order in which they were conducted.

Keese and Cleveland - 1966 (*)

Keese and Cleveland reported the findings of overhead sign studies at Texas Transportation Institute. A variety of sign treatments were evaluated. The addition of illumination to the button copy porcelain enamel sign improved legibility in the lowbeam, two-headlamp condition; the four headlamp low beam illumination gave satisfactory legibility without added sign illumination. Keese and Cleveland concluded that satisfactory legibility may be achieved under many conditions without the use of overhead sign lighting fixtures.

Woods, Rowan, and Johnson - 1970 (*)

Four years later, TTI conducted a "diagnostic" study concerned with improvement in highway signing. Each member of a six man diagnostic team drove for approximately 30 minutes and then observed as a second driver covered a route of the same length. The members of the team then expressed their opinions concerning the signs on the routes covered. The study report recommended all overhead signs be illuminated.

"Because automobile headlights do not provide effective illumination, all overhead signs on freeways and arterial systems should be provided with external lighting."

"On one study, however, the use of new high-intensity sheeting provided sufficient reflectivity on low beam to eliminate the need for external

*Descriptions of these studies are quoted from Reference 3.

illumination on both roadside and overhead signs. Since this type of material is not currently in general use, further study is necessary to ascertain the extent of its applicability without external illumination."

It should be kept in mind that these conclusions were based upon subjective impression. Objective performance data were not collected in this study.

Woods and Rowan - 1976 (Reference 16)

The basic objective of this study was to evaluate high-intensity (Type III) reflective sheeting for use on overhead signs without external illumination. The study was conducted because there were some indications that the legibility distance for non-illuminated signs using high intensity (Type III) sheeting was less than that for illuminated signs with engineering grade (Type II) sheeting.

The average legibility distances found by Woods and Rowan are noted below.

	Illuminated Sign (Type II material)	Non-Illuminated Sign (Type III material)
Low Beam Headlights	1381 feet	1119 feet
High Beam Headlights	1398 feet	1467 feet

In this case the observed legibility distance for the non-illuminated sign was 5 percent better than the illuminated sign when high beams were used. When low beams were used, the legibility distance was 19 percent less for the non-illuminated sign.

The authors state in their findings:

"The reduction in legibility distance under the low-beam and high-intensity sign configuration is undoubtedly cause for some

concern. However, the legibility distance provided is sufficient to read a complex message. [The authors note that a driver with 20/40 visual acuity would have 4.5 seconds of reading time.] Considering that the target value of the high-intensity sign is high and thus prepares the driver to read the message, and considering that field installations have been relatively successful, it seems reasonable to conclude that high-intensity overhead sign installations without external illumination can be effectively used when the background brightness is not excessive and when the minimum direct line of sight to the sign installation is at least 450 m (1500 ft)."

Robertson - 1976 (Reference 10)

At about the same time as the study by Woods and Rowan, Robertson also evaluated the feasibility of using high intensity (Type III) sheeting on overhead signs without external illumination. Robertson used a comparative technique in which two signs, side-by-side, on a single structure were compared. Five test sites (five pairs of signs) were evaluated. At each site one sign was refurbished with engineering grade sheeting (both background and legend) and remained illuminated. The second sign was refurbished with high-intensity sheeting and lighting fixtures disconnected.

At each test site luminance measurements of the sign legend and background were made using a telephotometer. In addition, observers viewed and rated the signs. Quoted below are Robertson's findings for three of the five test site locations

Site 1

"For a motorist traveling alone on the highway and using low beams the average luminance of the lighted conventional material was greater than that for the unlighted high-intensity material. Under stream traffic conditions, the average luminances of the conventional material were slightly higher than those for the high-intensity materials; however, the differences were not statistically significant within the visibility and legibility distances. The standard deviations revealed that the brightness of the high-intensity sign was much more uniform than that of the lighted conventional sign.

The majority of the 11 people viewing these signs stated that they first observed the conventional sign because of the bright spot created by the exterior lighting. However, they unanimously agreed that at 183 m (600 ft) the luminance appeared greater and more uniform for the high-intensity sign and that it was more legible than the conventional sign. Upon leaving the site, each person stated he or she would prefer the high-intensity sign."

Site 2

"In stream traffic, the average luminances of the two background materials were practically the same, although the brightness of conventional legend material was greater than that of the high-intensity material. The 13 people visiting this site responded in a similar manner to those who visited site 1, with the exception that one-third of the individuals

stated that they observed the high-intensity sign before the conventional sign."

Site 3

"The degree of illumination reaching the signs from the vehicle head lamps was limited because of the horizontal curve, and at all observation locations the brightness of the conventional sign was superior to that of the high-intensity sign. The 13 people who viewed these signs stated unanimously that the lighted conventional sign provided better visibility and legibility."

Robertson made the following conclusions and recommendations.

"Nonilluminated Straight Roadways

For signs erected over straight sections of roadway, there were no statistical differences in the brightnesses of the background materials for the two signs seen by motorists traveling in stream traffic. Although the average luminances of the high-intensity legend materials were not so bright as those of the illuminated conventional sign, the people who viewed the signs stated that the uniform brightness of high-intensity sign provided greater legibility than the illuminated sign with uneven light distribution. For a single vehicle travelling with high-beam lights, the high-intensity signs were much brighter; however, for the same vehicle using low beams, the luminance of the high-intensity signs was not so bright as that of the adjacent conventional signs."

"Nonilluminated Curved Roadways

On a curved approach, when only a limited amount of light from the vehicles was projected on the overhead signs, the luminances of the unlighted high-intensity materials were not sufficient to provide the motorists with the equivalent sign legibility and visibility obtained from the conventional signs."

"The foregoing conclusions indicate that the external lighting can be eliminated on many overhead signs through the use of high-intensity sheeting without adversely affecting the service to motorists. Consideration should be given to disconnecting or removing the illumination on existing and proposed high-intensity overhead signs on roadways that are susceptible to high-beam and steam traffic lighting conditions and that have a straight approach equal to or greater than the visibility recognition distance. The provision of external lighting on all overhead signs erected over curved sections of illuminated and nonilluminated roadways should be continued."

Caltrans - 1978 (Reference 9)

Caltrans conducted a major study in 1978 on "Use of Reflectorized Versus Illuminated Overhead Mounted Guide Signs." Two major elements of the Caltrans study are of interest to this state-of-the-art report. First, an extensive review of the literature was conducted. This review identified two studies which are not documented elsewhere in this state-of-the-art report. Second, a night survey of all overhead signs in four Caltrans Districts was conducted. Although no objective evaluation of different sign treatments was conducted, several conclusions were reached regarding sign legibility.

Regarding other studies, the Caltrans report cites a Swedish study which reported "that the attention value of signs with high illuminance material is superior to standard reflective material. For most normal conditions, lights can be replaced with high illuminance materials without reducing safety."

A 1976 report by the Ohio Department of Transportation is also cited. It is reported to state that "the most effective combination of materials is reflective button copy on engineering grade background." The Ohio report also observed that the brightness of some high intensity backgrounds on overhead guide signs tended to degrade legibility. The report concluded that enhancement of target value at the expense of legibility cannot be tolerated.

The night survey of overhead signs was conducted by engineering professionals on Caltrans' staff. Reproduced below are the findings and conclusions of that study team. It is emphasized that these findings and conclusions are based on the collective opinion of the study team based upon a review of studies conducted by others and their own nightime viewing of overhead signs.

- Encapsulated lens reflective sheeting used as background material interferes with the legibility of the message.
- Encapsualted lens reflective sheeting and reflector button copy function equally well in areas of low ambient lighting. However, when high ambient lighting is present, the reflective properties of both products are ineffective.
- Legibility of overhead guide signs is more important than target value. (What is important is the ability to read the message.)

- o Engineering grade reflective sheeting is inadequate for reflective copy under lights out conditions.
- o Illuminated signs are superior in target value and legibility.
- o Reflective copy on opaque background has quicker legibility than on reflective sheeting background due to the halation effect of the bright background.
- o High beam headlights greatly increase the reflectivity of both reflector buttons and reflective sheeting on overhead signs.
- o Engineering grade copy is not an acceptable material for legends on overhead signs.
- o Although reflective sheeting background is more pleasing in appearance, both reflective sheeting and opaque background with reflective copy are equal in target value.
- o At certain favorable locations where climatic conditions and ambient lighting are not detrimental to the sign performance, properly reflectorized overhead signs need not be illuminated.
- o Non-illuminated reflectorized signs perform poorly under high ambient light conditions, whether the light is in front of or in back of the sign.

Bryan - 1978 (Reference 1)

This study, by the Pennsylvania Department of Transportation, was similar in scope to the 1976 study by Robertson. A side-by-side comparison of different sign treatments was employed at two test sites. Luminance

measurements were made using a telephotometer. A total of 572 motorists were interviewed to seek their opinion of different sign treatments.

The first test site had reflector button legend on a porcelain enamel background on one sign and high intensity legend and background on the other sign. The second test site had reflector button legend on engineering grade background on one sign and reflector button legend on high intensity background on the second sign. Signs were not illuminated at the second test site. The first test site was evaluated under two conditions: 1) no external illumination; 2) external illumination of the porcelain enamel sign.

After passing the sign location motorists were asked: 1) which sign they saw first; 2) which sign they found easiest to read; and 3) which sign they preferred.

The study concluded that an acceptable level of service can be provided by:

1). Reflector button legend on an opaque background (illuminated); or

2). Reflector button legend on an engineering grade background (non-illuminated) provided that there is a tangent section a minimum of 1200 feet in length.

Caltrans - 1981 (Reference 7)

As a follow-up to its 1978 study Caltrans undertook a second effort which was reported in 1981. As a part of this second effort a team of 14 professionals (mostly engineers) measured legibility distance for various types of overhead sign treatments at different locations throughout the state.

Nine professionals observed legibility distance for 33 sign structures on the Pasadena Freeway under conditions of both "lights on" and "lights

off." These signs had reflector button legends on opaque backgrounds. Caltrans stated that these observations "indicated that the performance of button copy compares closely with externally - illuminated copy in legibility."

Jones - 1983 (Reference 12)

The Texas State Department of Highways and Public Transportation conducted field studies of legibility for illuminated and non-illuminated signs. Legibility studies were performed in Houston, Dallas and El Paso. Thirty seven observers, male and female, in different age brackets were used. Signs were observed that contained reflective and opaque backgrounds, button and high intensity stick on copy. Signs were observed with and without sign illumination and with, and without freeway illumination.

The legibility studies indicated that there are no significant differences in legibility distances between lighted and unlighted signs. A reflective background merely added conspicuity and did not increase the legibility distance of the sign. For the signs observed in the Houston area the average legibility distance for the illuminated signs was 877 feet. For the non-illuminated signs it was 838 feet. Twenty-one observers took part in the Houston study.

The 1983 Texas study did not use a group of observers which corresponded to the population mix (age) in the United States and the number of observers was insufficient to make strong statistical tests of differences in legibility distance. Texas has recently completed a follow-up study using a much larger number of observers which represents the U.S. population mix. Although the results have not been published, Mr. Jones has stated in a telephone conversation that the study showed no statistically

significant difference in legibility distance for illuminated versus non-illuminated signs.

Harmelink - 1984 (Reference 4)

One of the more recent studies was conducted by the Ontario Ministry of Transportation and Communications. Thirty signs were evaluated representing various combinations of legend and background materials as noted below.

		LEGEND		
		Engineering Grade	Super Engineering Grade	High Intensity
BACKGROUND	Engineering Grade	X	X	X
	Super Engineering Grade		X	
	High-Intensity			X

None of the signs were illuminated. Nineteen observers viewed the signs and subjectively evaluated them in terms of brightness, legibility, adequacy, and glare.

Study results showed that for signs mounted directly ahead of the observer there was no significant difference in the observers' evaluation of legibility. When mounted slightly to the right, however, there were statistically significant differences in the observers' judgement of legibility. The high-intensity legend on an engineering grade background scored better than a high-intensity legend on a high-intensity background. Both were significantly better (statistically) that those treatments that did not have high intensity legends.

Upchurch and Bordin - 1986 (Reference 17)

This study compared the performance of ten different systems for illuminating overhead signs in terms of legibility distance and other factors. Although not a major part of the study, legibility distance for two non-illuminated signs (one with an opaque background and one with a high intensity background) was also evaluated. Legibility distance for the non-illuminated signs was found to be less than the illuminated signs. However, the difference in legibility distance was not statistically significant.

Summary

The findings of the studies reported above clearly are not unanimous. Each experimental design which was used was subject to some limitations; this may account for the variation in conclusions. There may be a consensus which has developed out of the previous work. It may be best described by quoting Gordon's synthesis on "Night Visibility of Overhead Guide Signs."

> "For typical, uncomplicated freeway applications, the legend-background treatments in common use can all give satisfactory legibility. A possible exception is the marginal legibility of nonilluminated signs viewed under the lowbeam illumination of a single vehicle. Auxiliary illumination may be required on curved roads, at locations were adverse weather is prevalent, under conditions of high ambient illumination, and at sites where immediate action by the driver is required."

OTHER FACTORS

Studies have shown that motorists prefer illuminated signs and signs with reflective backgrounds over opaque backgrounds. Bryan (1) presented

the motorist the opportunity to view two different sign treatments side-by-side. Motorists favored an illuminated sign over a non-illuminated sign having a reflector button legend on an opaque background by about a two to one margin. By the same margin motorists preferred a Type III background over a Type II background. The two-to-one margins show that motorist preference is far from unanimous.

Harmelink (4) found that observers had a marked preference for signs having a high intensity legend on an engineering grade background.

Gordon (3) cites other studies where drivers preferred retroreflective backgrounds.

COST CONSIDERATIONS

A preceding section of this report identified several economic factors affecting selection of the type of sign treatment. This section includes a review of three research studies, conducted by others, which complied cost comparisons of non-illuminated versus illuminated signs.

Caltrans (9) investigated the placement of high intensity reflective sheeting on exiting signs having reflectorized button legend on an opaque background (a porcelain enamel such as Arizona now uses). The average cost per sign for this treatment was about $1,325. The reflective sheeting background would have to be replaced about every 10 years. Offsetting the cost of the reflective sheeting was an annual savings of about $300 in electric power and relamping costs. Other electrical maintenance costs (ballasts, circuitry, etc.) would be eliminated.

A 1981 Pennsylvania study (1), calculated the costs associated with three signing policies. The alternatives were:

Option "A: - Maintain lighting on 100 percent of the overhead signs.

Option "B" - Provide lighting on 80 percent of the signs. The other 20 percent would be fitted with high intensity sheeting for the background (estimated life of 10 years).

Option "C" - Same as B, but engineering grade sheeting (estimated life of 7 years) would be used rather than high intensity sheeting.

Following option "B" rather than option "A" would save $168 per sign per year on those signs converted to high intensity sheeting. Conversion from option "A" to option "C" would save $180 per sign per year.

Robertson (11) calculated the cost of using high intensity sheeting as a substitute for sign illumination. Costs were figured for installing light fixtures and overhead walkways, and energy and maintenance charges were also considered.

Installation Costs: The cost of a sign lighting fixture was estimated as $400 or more. The average number of fixtures on a sign installation project was 2.55; 1.59 signs on average were placed on each structure. The average cost of lighting each structure was therefore figured as $1,600.

Overhead Sign Structures: - Walkways are required for mounting and maintaining the lighting fixtures. These constructions cost anywhere from $225 to $250 per foot. A walkway on an average cantilever structure was calculated as costing $7,125, on an average span structure as $24,500.

Energy Costs: In 1974, the annual electricity costs for fluorescent lighting on a typical overhead Virginia sign was between $35.82 and $113.02. Robertson considered $71.35 as a typical average.

Maintenance Costs: In the Salem District, maintenance of lighting on 49 signs cost approximately $4,350, with unit cost per sign of $89. This cost

includes labor, equipment and materials. Maintenance in the Richmond and Suffolk Districts, done by outside contractors on an hourly basis, cost $192 and $128 per sign, respectively, excluding the cost of traffic control.

Robertson believed that lighting could be replaced by encapsulated lens sheeting on approximately 45 percent of the 1,170 overhead signs in Virginia (those located on straight roadways). If the 520 signs located on straight approaches were refurbished with encapsulated lens materials and the lights disconnected, an annual savings of approximately $83,000 ($160 per sign) could be achieved in electrical and maintenance costs. This savings does not include other benefits, such as the reduced exposure of maintenance personnel to traffic, improved services to motorists, the availability of maintenance crews and equipment for other work, and the reduction in time required for night inspections to locate malfunctioning lights.

Robertson also estimated that elimination of lights on tangent sections of the then planned I-495 freeway, could save $7,030 per structure, for a total of $520,000 in installation costs ($402,000 for structures plus $118,000 for lighting fixtures). These costs and savings were calculated on the basis of 1974 figures. Present costs would be considerably higher.

In addition to the above studies-which compared the cost of illuminated versus non-illuminated signs - Upchurch (17) conducted economic analyses of ten different systems for sign lighting. Table 2 presents a summary of the costs for the least expensive and most expensive systems evaluated.

Table 2. COSTS FOR TWO SIGN LIGHTING SYSTEMS

	Least Expensive System	Most Expensive System
Initial Cost	$254.77	$1,159.02
Annual Operating Cost	85.09	287.01
Annual Owning* and Operating Cost	115.02	432.15

* Annual Owning Cost is the initial cost of a system amortized over its projected life.

STANDARDS AND CURRENT PRACTICE

This section describes existing standards which apply to the selection of non-illuminated versus illuminated overhead guide signs and also reviews current practices regarding usage of non-illuminated overhead guide signs.

The Manual on Uniform Traffic Control Devices establishes basic guidelines or standards for the illumination or reflectorization of overhead guide signs. Section 2A -16 states that "All overhead sign installations should be illuminated where an engineering study shows that reflectorization will not perform effectively." The section goes on to say that, "In general, where there is no serious interference from extraneous light sources, reflectorized signs will usually be adequate. However, on expressways where much driving at night is done with low beam headlights, the amount of headlight illumination incident to an overhead display is relatively small. Therefore, all overhead sign installations should normally be illuminated." Section 2E-6, which deals with guide signs on expressways, states that "....all overhead installations should normally be illuminated." Section 2F-13, which deals with guide signs on freeways, states that "....the background of all overhead signs that are not independently illuminated shall be reflectorized." The MUTCD clearly states, therefore, that if overhead guide signs are not illuminated, they must be reflectorized. The full text of the MUTCD sections quoted above are reproduced in Appendix A.

FHWA Notice N5040.17 (2) supplements the MUTCD guidelines/standards. It permits the use of encapsulated lens reflective backgrounds in lieu of independent illumination provided, (1) the installation is in a rural environment; (2) an approach tangent not less than 1200 feet exists; and (3) a uniform vertical alignment is present. Regarding urban areas, the notice

states that "external sign illumination is considered necessary in most cases. Where conditions are such that satisfactory performance can be expected in urban areas without external lighting, this may be permitted on a limited basis." A copy of Notice N5040.17 is reproduced in Appendix B.

Other organizations and agencies, besides the federal government, have developed their own policies or recommendations regarding lighting/reflectorization of signs. In 1981 the Western Association of State Highway and Transportation Officials completed a task force effort on overhead sign lighting. The objectives of the task force effort were to: (1) Draft a position paper addressing current MUTCD guidelines and FHWA standards, and (2) develop criteria for not lighting overhead signs.

The WASHTO task force presented the following recommendations (13).

1. All overhead guide, information and service signs shall have reflective legends and borders.
2. All overhead warning and regulatory signs shall have reflective backgrounds. In addition, they should normally be illuminated.
3. Overhead exit direction guide signs and other overhead signs requiring an immediate response or lane change should normally be illuminated. Consideration should be given to providing reflectorized backgrounds as well as independent illumination at locations found to be critical or where driver expectancies are violated.
4. Overhead information, service and advance guide signs will not normally require independent illumination. They should, however, have reflective backgrounds unless an engineering analysis shows that non-reflective backgrounds will perform effectively.

Actual practices in individual states demonstrate a wide range of treatments for overhead signs. A 1977 report by Olson and Bernstein (6) reported on treatments then used by 39 states and ten turnpike authorities. Use of button copy on opaque background (the treatment currently used in Arizona) was a major type of treatment used by over one-fourth of the jurisdictions surveyed. The survey did not indicate how many of the signs having button copy on an opaque background are illuminated.

Table 3 tallies more recent data on the types of materials used by the 50 states as collected by the 3M Company. This data is for signs that are not illuminated. Only three states have non-illuminated signs with opaque backgrounds.

Regarding illumination versus non-illumination, then current practices were survey and reported by Kobetsky (5) in 1981.

Table 3

Number of States Using Various Materials on Non-Illuminated Overhead Guide Signs

Background Material		Copy Material*	
Opaque	3	Opaque	1
Engineering Grade Reflective Sheeting	16	Reflector Button	21
Hi-Intensity Reflective Sheeting	38	Engineering Grade Reflective Sheeting	4
		Hi-Intensity Reflective Sheeting	35

* "Copy" consists of legend and border

Note: Totals add up to more than 50 because some states use more than one type of material.

Seventeen states reported that their agency has a policy to light all overhead signs. Several agencies have a policy that when signs are not lighted they use either a high-intensity or super bright grade of reflective sheeting. Several agencies also reported that their policy to light signs was based on the importance of the sign or the environment within which the sign is located.

From the survey, it was reported that, on the average, 68 percent of all the overhead signs are externally illuminated. However, eight agencies reported that they light 10 percent or less of their overhead signs, while 26 agencies reported lighting over 90 percent of their overhead signs.

One final practice to note is the Illumination Engineering Society's "Recommended Practice for Roadway Sign Lighting." That document includes the following guidelines.

> Traffic signs mounted on overhead structures may require lighting for adequate nighttime discernment of the message, especially in urban areas because:
>
> (1) Reflectorization alone may not provide sufficient advance sign legibility due to the design of vehicle headlighting systems, i.e., the diversion of the main beams downward, and the vertical and horizontal alignments of the roadways on the approach to the sign.
>
> (2) Roadway lighting does not serve to properly activate or light overhead reflectorized signs. However, proper placement of roadway luminaires in advance of an overhead sign will serve to provide some beneficial sign illumination when the sign lighting is out of service. Proper roadway luminaire placement will eliminate the sign's distracting

shadow on the pavement which results when luminaires are placed behind the sign.

(3) Sight distance for sign recognization is increased.

RECOMMENDATION FOR FURTHER RESEARCH

The review of previous research suggest that, for many freeway applications, non-illuminated signs with reflectorized backgrounds will provide satisfactory legibility. Previous research also strongly suggests that non-illuminated, reflectorized background treatments can be economically competitive with or less expensive than illuminated systems.

It is recommended that further research be done to compare the cost of different sign treatments for Arizona conditions. This would include a comparison of the standard high pressure sodium illumination system now used in Arizona with various non-illuminated systems. It would also include a cost analysis for retrofitting existing opaque sign panels with reflectorized backgrounds.

Previous research, through field studies using observers, has shown that non-illuminated signs can perform satisfactorily. The number of studies which have been performed and the number of observers used in these studies makes it unlikely that new or different findings would result if Arizona conducted observer studies using the general population of drivers. It would be worthwhile, however, to have ADOT traffic engineering personnel observe various sign treatments so that they would see, firsthand, the advantages and disadvantages of different sign treatments. Therefore, it is recommended that side-by-side comparisons of different sign treatments be installed in the field for evaluation by ADOT personnel.

The review of the literature identified two potential problems with the use of high intensity sheeting on laminated sign panels. First, the manufacturer will not guarantee this product when overlaid on laminated sign panels. Second, the State of Pennsylvania has experienced major problems with laminated sign panels. Because Arizona uses laminated sign panels on

existing signs, it would be important to learn more about the shortcomings of this type of panel before a retrofit of reflective sheeting is considered.

DETAILED WORK PLAN

TASK 1 - EVALUATE SIGN PANELS

Evaluate existing sign panels for any potential problems in applying a reflective sheeting background. This evaluation will include the validity of manufacturer guarantees on various types of sign panels and a review of problems reported by other states.

TASK 2 - CONDUCT ECONOMIC ANALYSIS

Conduct an economic analysis to determine the equivalent annual cost for five sign treatments. The sign treatments shall be:

Legend and Border	Background	External Lighting
Reflector Buttons	High Intensity Reflective Sheeting	Non-illuminated
Reflector Buttons	Engineering Grade Reflective Sheeting	Non-illuminated
High Intensity Reflective Sheeting	High Intensity Reflective Sheeting	Non-illuminated
High Intensity Reflective Sheeting	Engineering Grade Reflective Sheeting	Non-illuminated
Reflector Buttons	Porcelain Enamel	Illuminated with 150 watt High Pressure Sodium lamp in a Holophane Panel-Vue fixture.

The economic analysis shall include both initial installation costs and annual operating costs. Initial installation cost for non-illuminated systems shall include:

Materials (Reflector buttons, reflective sheeting, and sign panel)

Labor

Other installation costs.

Initial installation costs for the illuminated system shall include:

Materials (Reflector buttons and reflective sheeting)

Lamp, fixture, and ballast

Labor

Power service

Incremental costs for the sign structure due to overhead lighting fixture supports and catwalks

The service life and salvage value of each treatment shall be considered in determining the equivalent annual cost. Periodic replacement of the legend and background shall be included for the non-illuminated systems. For the illuminated system, periodic replacement of the lamp, ballast, and fixture shall be considered as well as the annual costs for washing, relamping, and other maintenance, and electric power.

Separate economic analyses shall be done for treatments for new signs and for existing signs. For existing signs it shall be assumed that a reflectorized button legend and a porcelain enamel background exists and that a power supply is present at the sign structure. If appropriate, the economic analysis shall consider different methods of applying reflective sheeting (background) to the sign panel. If appropriate, the economic analysis shall consider any problems with using existing sign panels as identified in Task 1.

Any other identifiable and quantifiable costs should be included in the economic analysis.

TASK 3 - EVALUATE OTHER FACTORS

Evaluate other advantages and disadvantages of each of the five sign treatments which cannot be quantified in an economic analysis. These may include, but are not limited to, the following.

Cost of traffic control when maintenance is performed - Both costs to the agency and cost to the motoring public.

Worker safety.

Light pollution impacts.

TASK 4 - FIELD TEST SIGN TREATMENTS

NOTE: Task 4 will be performed only if Task 2 finds that a non-illuminated system is cheaper than or reasonably close to the equivalent annual cost of the illuminated system.

Conduct a subjective evaluation of illuminated versus non-illuminated sign treatments using a side-by-side comparison. Two of the four non-illuminated sign treatments will be selected for evaluation. These two sign treatments will each be compared to the illuminated system.

Observers for this evaluation will be approximately 10 to 15 ADOT traffic engineering personnel. Criteria to be evaluated may include conspicuity (target value), legibility, lighting uniformity, color rendition, viewing comfort, overall preference, and others.

Two different locations shall be used for the side-by-side comparison. Four different conditions will be evaluated as described below.

	Left Sign	Right Sign
LOCATION A		
Condition 1	Reflector Button legend Porcelain enamel back-ground Standard HPS illumination	Non-illuminated sign treatment I (reflectorized legend and back-ground) Standard HPS illumination
Condition 2	Same as Condition 1	Same as Condition 1 except no illumination
LOCATION B		

Condition 3	Same as Condition 1	Non-illuminated sign treatment II (reflectorized legend and background) Standard HPS illumination
Condition 4	Same as Condition 1	Same as Condition 3 except no illumination

The two locations, on the Phoenix area freeway system, will be chosen in cooperation with ADOT personnel.

TASK 5 - RECOMMEND SIGN TREATMENTS

Based upon the findings of Tasks 1, 2, 3 and 4, recommend (a) sign treatment(s) to be used by the Arizona Department of Transportation. If different treatments are to be used in different situations, they shall be specified. If sign treatments different from exiting policy are recommended, a new draft policy for possible adoption by ADOT shall be prepared.

TASK 6 - PREPARE FINAL REPORT

Prepare a final report documenting the analyses and findings of the research project.

ANTICIPATED PROJECT DURATION: 7 months.

Note: Task 4 is optional. If Task 4 is deleted the project duration is estimated to be 4 months.

ESTIMATED BUDGET: $38,000

Notes: The budget includes the cost of purchasing materials and installing reflectorized backgrounds on two sign panels for Task 4.

The budget does not include the cost of installing HPS lighting systems for Task 4.

Task 4 is optional. If Task 4 is deleted the budget is estimated to be $17,500.

LIST OF REFERENCES

1. Bryan, N., Klotz Jr., R., Kinsley, H., and Casner, D. Limited Evaluation of Reflective and Non-Reflective Background for Overhead Signs. Pennsylvania Department of Transportation Bureau of Materials, Testing and Research, Harrisburg, Pennsylvania. September, 1978.

2. Federal Highway Adminstration, Encapsulated-Lens (High-Intensity) Reflective-Sheeting Sign Material, Notice N5040.17, June 15, 1976.

3. Gordon, D. Night Visibility of Overhead Guide Signs: A Review of the Literature, Report Number FHWA/RD-84-087. Federal Highway Administration, Washington, D.C. October, 1984.

4. Harmelink, M., et., al. Evaluation of Reflectorized Sign Sheeting for Non-Illuminated Freeway Overhead Guide Signs. Transportation Research Board Record 1010. 1985.

5. Kobetsky, K. Illumination of Overhead Signs. Paper presented at Annual Meeting of the Southern Association of State Highway and Transportation Officials. October, 1981.

6. Olson, P. L. and Bernstein, A. Determine the Luminous Requirement of Retroreflective Highway Signing. Highway Safety Research Institute, University of Michigan. Report No. UM-HSRI-77-6. 1977.

7. Overhead Guide Sign Review Team, California Dept. of Transportation. Establishing Priorities for Operation and Maintenance of Overhead Guide Signs. California DOT. March, 1981.

8. Pennsylvania Department of Transportation. "An Evaluation of Alternate Materials for Guide Signs on Expressways and Freeways." Bureau of Highway Services Traffic Engineering and Operations Division, Harrisburg, PA, October, 1980.

9. Reflective Sheeting Study Team, California Dept. of Transportation. Use of Reflectorized vs. Illuminated Overhead Mounted Guide Signs. California DOT. August, 1978.

10. Robertson, R. N. Evaluation of High-Intensity Sheeting for Overhead Highway Signs. Transportation Research Record 611, Washington, D.C., 1976.

11. Robertson, R. N. and Shelor, J. D. Using Encapsulated-Lens Reflective Sheeting on Overhead Highway Signs. Transportation Research Record 628, 1977.

12. Jones, H. Dexter, Raska, Joseph G., and McNees, Roger W. Evaluation of Overhead Sign Background Materials and Mercury Vapor Sign Lighting Fixtures, Report Number 222-2F. Texas State Department of Highways and Public Transportation, Austin, Texas, August, 1983.

13. WASHTO Task Force on Overhead Sign Lighting. Final Report. Western Association of State Highway and Transportation Officials. September, 1981.

14. Woltman, H. L. and Youngblood, W. P. "An Assessment of Indirect Factors Affecting Reflective Sign Brightness." Unpublished Transportation Research Board Preprint.

15. Woltman, H. L. and Youngblood, W. P. Indirect Factors Affecting Relative Sign Brightness. Transportation Research Record.

16. Woods, D. L. and Rowan, N. J. Overhead Signs Without External Illumination. Transportation Research Board Record 611, pp. 38-44, 1976.

17. Upchurch, J. E. and Bordin, J. T. Evaluation of Alternative Lighting Systems for Guide Sign Illumination. Arizona Department of Transportation. April, 1986.

2A-16 Illumination and Reflectorization

Regulatory and warning signs, unless excepted in the standards covering a particular sign or group of signs, shall be reflectorized or illuminated to show the same shape and color both by day and night. All overhead sign installations should be illuminated where an engineering study shows that reflectorization will not perform effectively. Reflectorization, non-reflectorization, or illumination of guide signs shall be as provided in subsequent sections.

2A-17 Means of Illumination

Illumination may be by means of:

1. A light behind the sign face, illuminating the main message or symbol, or the sign background, or both, through a translucent material; or
2. An attached or independently mounted light source designed to direct essential uniform illumination over the entire face of the sign; or
3. Some other effective device, such as luminous tubing or fiber optics shaped to the lettering or symbol, patterns of incandescent light bulbs, or luminescent panels that will make the sign clearly visible at night.

The requirements for sign illumination are not considered to be satisfied by street or highway lighting, or by strobe lighting.

2A-18 Means of Reflectorization

Reflectorization may be by means of:

1. Reflector "buttons" or similar units set into the symbol, message and border; or
2. Reflective sheeting, either on the sign background or where a white legend is used on a black or colored background in the symbol or message and border.

GUIDE SIGNS - EXPRESSWAYS

2E-6 Reflectorization or Illumination

Letters, numerals, symbols, and borders shall be reflectorized. The background of expressway guide signs may be reflectorized or nonreflectorized. However, the mixing of signs with reflectorized and nonreflectorized backgrounds in the same general area should be avoided.

In general, where there is no serious interference from extraneous light sources, reflectorized signs will usually be adequate. However, on expressways where much driving at night is done with low beam headlights, the amount of headlight illumination incident to an overhead sign display is relatively small. Therefore, all overhead sign installations should normally be illuminated. The type of illumination chosen should provide effective and reasonably uniform illumination of the sign face and message. When a sign is internally illuminated the requirement for reflectorized legend and borders does not apply.

GUIDE SIGNS - FREEWAYS

2F-13 Color, Reflectorization, and Illumination

Color, reflectorization and illumination of freeway guide signs shall conform to the provisions for expressway guide signs set forth in sections 2E-5 and 2E-6. In addition, the background of all overhead signs that are not independently illuminated shall be reflectorized. When a sign is internally illuminated the requirements for reflectivity do not apply.

Technological developments have produced a variety of types of illumination for highway signs. Internally illuminated signs, having translucent faces, are especially effective for freeway use. Their use may be justified for some installations. Where internal illumination is used, the sign colors shall appear essentially the same by night and by day.

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

SUBJECT	FHWA NOTICE
Encapsulated Lens (High Intensity) Reflective Sheeting Sign Material	N 5040.17 June 15, 1976

1. PURPOSE. To transmit to FHWA offices and to State highway agencies the results of a study on the use of encapsulated lens reflective sheeting.

2. BACKGROUND. A joint study team from the Offices of Engineering and Traffic Operations and Research and Development evaluated the performance experience of encapsulated lens reflective sheeting in five States, each of which had several years of experience with this material. The study indicated that encapsulated lens reflective sheeting in use for several years has exhibited greater durability than conventional enclosed lens (engineering grade) sheeting. Reports of accelerated weathering test and field experience indicate that the expected life of this newer material may exceed the manufacturer's 10-year warranty by a factor of 20 to 50 percent.

   The increased service life can offset the higher initial cost of encapsulated lens sheeting, resulting in annual signing costs which are equal to, or lower than, costs for signs with conventional materials. In view of the cost factor, and other utility characteristics described in Attachment A, use of encapsulated lens reflective sheeting is now removed from the experimental category.

3. ACTION. The Office of Traffic Operations will prepare an addition to the Federal-Aid Highway Program Manual regarding the use of encapsulated lens reflective sheeting. The safety importance attached to this use warrants full immediate availability of the material on Federal-aid highway projects. Pending issuance of a formal directive, guidelines for immediate use are set forth in the next paragraph.

4. GUIDELINES. On Federal-aid projects encapsulated lens reflective sheeting may be approved for use as legend and/or background material on guide signs and other types of highway signs where the increased durability will result in lower overall signing costs and other factors make the use of this material desirable. As a general

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rule, encapsulated lens material should not be used on any sign where the expected life of that sign is less than 5 years. Where the expected life of a reflective sign does not exceed 5 years, engineering grade reflective sheeting normally should be used.

In rural areas, where encapsulated lens material is used on refurbished overhead guide signs installed on tangent roadways having a constant grade approach for at least 1,200 feet prior to the sign, the State may consider elimination of external sign lighting. After existing signs in these areas have been refurbished, each location should receive an onsite nighttime evaluation of the sign with and without illumination under all adverse weather conditions. Once the State has developed some conclusions as to what specific types of rural environments do not require sign lighting, these installations should be reviewed by division office personnel for adequacy in meeting drivers' signing needs. FHWA will continue evaluating the need for external illumination on new overhead signs that are fabricated with encapsulated lens materials and are located in rural areas and would like to receive suggested criteria from the States with comments from the division office on the adequacy of the criteria.

In urban areas, external sign illumination is considered necessary in most cases. Where conditions are such that satisfactory performance can be expected in urban areas without external lighting, this may be permitted on a limited basis. Conditions to be considered would be the human factors questions concerned with meeting drivers' needs, target value, and legibility distances. Evaluations of such completed installations should be sent to the Office of Traffic Operations.

For safety purposes, encapsulated lens reflective sheeting may be approved for use as legend and/or background material on selected regulatory or warning signs for use in areas where the degree of hazard or potential hazard is greater than for normal conditions. Such signs would include reversed screened regulatory signs where dark colors sharply reduce the reflectivity, orange warning signs used in construction and maintenance areas that are typically rigidly mounted and require night visibility, and reversed screened highway route markers and their auxiliary panels. When an agency determines that a brighter material is needed for improved conspicuity at specific locations encapsulated lens sheeting may be approved for use on signs that last less than 5 years.

FHWA Bulletin N 5040.17
June 15, 1976

Attached to this Notice is a set of Guide Specifications for Sheet Reflective Materials prepared by a Task Force of the AASHTO-AGC-ARBA Joint Committee in 1973. It is recommended that these or similar specifications be used for projects incorporating encapsulated lens reflective sheeting.

At the present time most encapsulated lens sign sheeting materials are available only as a sole source commodity. Based on the staff study results, the use of these materials is considered to be in the public interest and such requests for use may be approved by the Division Administrator when in his judgment the specific use proposed is justified.

L. P. Lamm
Executive Director

Attachment

Report On The Use Of Encapsulated Lens ("High Intensity") Reflective Sheeting

The following report is based upon a review of available data including performance data obtained from visits to five States by a joint study team from the Offices of Engineering and Traffic Operations and Research and Development.

Encapsulated lens reflective sheeting sign materials have generated considerable interest in the highway engineering community and are presently being utilized to some degree, at least experimentally, by over 80 percent of the State highway organizations.

This material has a specific brightness that is about three times as great as the more commonly used enclosed lens sheeting. Although there remains some lack of complete factual data on the performance of this product, it does appear that the encapsulated material, despite its high initial cost, can be justified because of its superior durability and maintenance characteristics.

Increased Durability and Reduced Maintenance

Several States began testing encapsulated lens materials in the early 1960's; however, only limited quantities were placed prior to 1967. Field experience indicates an expected life of 12 to 15 years or approximately twice as long as enclosed lens materials. Several signs have been observed that have been in use for 7 to 10 years and none had yet developed indications of significant deterioration. This agrees with the results of accelerated weathering tests performed by the Kentucky Department of Highways (1). The enclosed lens materials deteriorated rapidly and failed at an average of 2,100 hours exposure in the Weatherometer, whereas the encapsulated material lasted approximately 7,000 hours. While such weathering tests are only poorly related to the field life of the material, a general rule-of-thumb indicates that 1 hour in the Weatherometer is equivalent to 18 hours of weathering in the field. Therefore, the enclosed lens would have a life expectancy of slightly more than 4 years (without maintenance) while the encapsulated material reached the equivalent of 14 years. Additional weatherometer data has been developed by the Illinois Department of Transportation that substantiates the earlier results. Some samples have been exposed to more than 9,000 hours of tests and have retained more than 85 percent of their original reflectivity values.

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The manufacturer is currently guaranteeing the encapsulated material for a minimum service life of 10 years. The enclosed lens material generally will last about 7 years. In some cases the enclosed lens material requires a coating with a lacquer-type material ("Clearcoat") just before the surface starts to crack and craze, usually at the end of the fourth year. However, most States do not appear to be utilizing this process of extending the life of the material. The encapsulated material has no maintenance requirement to obtain its full rated life. The material can be washed with soap and water, but in most environments it has been found that normal rainfall is sufficient for cleaning purposes.

Minor problems have been reported regarding use of encapsulated lens sheeting material. These problems involve wrinkling, pullback, and color matching of the material. Delamination problems developed due to overheating but were solved by modification of sign applicators. Also, several States reported additional care must be exercised in the transportation of finished signs.

A major problem involving the blackening or corrosion of high intensity material has developed in Louisiana. The corrosion problem has occurred only on the green materials. A large number of signs are being refurbished at the expense of the manufacturer who claims the corrosion problem has been solved.

Effect of Durability on Signing Costs

The importance of the greater durability of the encapsulated lens material becomes apparent when the costs of signs are analyzed. The current cost of the encapsulated lens material in sheet form is $2.00 per square foot. Enclosed lens material is $1.25 per square foot, or a difference in the basic material cost of approximately $0.75 per square foot. The encapsulated material is also slightly more expensive to fabricate due to required modification of sign shop applicators. This has been estimated to add an additional $0.10 per square foot to the cost of a sign.

The useful life of encapsulated lens material is conservatively estimated at 10 years compared to 7 years for the enclosed lens materials. Therefore, if a small ground mounted sign cost $5.51 per square foot (average cost quoted in Virginia (2) including enclosed lens sheeting, backing, fabrication, wood post, mounting hardware, labor, and equipment costs), then the cost per year during its useful life is $5.51/7) = $0.79 per square foot. With the encapsulated material this cost would be ($5.51 + 0.75 + 0.10)/10 = $0.64 per square foot or

a savings of approximately $0.15 per square foot per year of useful life. This savings is only realized if the sign is utilized for its full useful life. Therefore, in areas where theft and vandalism cause the signs to be replaced at a higher than necessary frequency, the increased durability of the encapsulated material will be of marginal utility.

On larger signs, where the structural supports are likely to be such that the signs will be refurbished in the field, even greater savings can be realized. For example, on a typical overhead sign bridge the structure will last at least 20 years. During that period, enclosed lens signs will require one replacement of the sheeting. Considering this difference in maintenance cycles and the labor involved in changing over signs in the field (including the need for closed traffic lanes) a crude estimate reveals savings of nearly 20 percent for encapsulated lens material on major signs.

Decreasing Need for Illumination of Overhead Signs

Additional savings over and above those due to its increased life can be realized in certain applications. The encapsulated lens material has a specific reflectivity about three times as great as enclosed lens material. Under certain geometric constraints, the encapsulated materials perform effectively when illuminated only by low-beam headlamps from the motor vehicle. The enclosed lens materials, in the same location, would require external sign illumination. Recent tests conducted by the Virginia Highway and Transportation Research Council (3) have concluded that overhead signs employing encapsulated lens sheeting, without external illumination, have adequate legibility and target value where the sign is approached on a rural, constant grade, tangent roadway at least 1,200 feet long.

Therefore, in rural areas when signs on overhead structures with straight approaches are refurbished with the encapsulated material, the State may consider elimination of existing sign lighting as a means of providing significant energy and maintenance savings. Illumination should not, however, be turned off at any rural location where the roadway approaching the overhead sign has a horizontal or vertical curve within 1,200 feet of the sign (3). Also, in areas where frost and dew persistently cause reflectorized signs to lose their effectiveness, external lighting should remain. Each location should receive an onsite nighttime evaluation with and without sign lighting to determine whether external illumination can be turned off. The average annual power cost for a typical

illuminated sign is reported to be $71.35 (4). Maintenance cost for this sign is approximately $100 per year when done by State personnel and considerably more when a contractor is employed. With these figures, savings of about $175 per year can be realized for each sign when existing sign lighting is turned off.

Elimination of external sign illumination is questionable in urban areas, especially in areas which typically have fixed roadway lighting, extraneous light sources, and complex geometric designs. This may not be the case in cut sections where the environment is more similar to that of rural areas. In most urban cases, however, greater attention value and legibility of the sign message appear to be required than can be obtained without the aid of external sign illumination. Therefore, external sign illumination is highly recommended on all overhead signs located in urban areas, regardless of material used.

New Overhead Signs

In the case of new overhead signs on constant grade, tangent approaches in rural areas, additional savings can be made if the initial design employs encapsulated lens material. Because reflectorization with encapsulated materials will perform effectively in normal situations, exterior sign lighting may not be required on signs where an engineering analysis determines the lighting is not needed. A saving of about $400 per luminaire can result where external lighting can be eliminated (4). In addition, maintenance catwalks, required only to maintain the lighting system, may no longer be required. Elimination of the sign catwalk would produce an average savings per structure of about $7,000. By eliminating sign lighting at suitable locations where new overhead signing will be installed, savings of approximately $8,500 per sign could be obtained.

Non-Monetary Benefits

In addition to the above savings, there are other non-monetary benefits which should be considered. Non-illuminated signs with encapsulated lens sheeting material will require less maintenance. Maintenance or contract crews and the traveling public will not be exposed to the hazard of work under traffic conditions as often or for as long a period of time. The results will be less disruption to traffic and improved service to motorists. The size of maintenance forces and the need for night inspections may possibly be reduced. Also, improved guidance to motorists will be provided during adverse weather and during power failures.

References

1. Rizenbergs, R. L., "High Intensity Reflective Materials for Signs," Kentucky Research, Report No. 363, May 1973.

2. Robertson, R. N., "Use of High Intensity Reflective Materials in Highway Signing - A Literature Review," Virginia Highway Research Council, Report No. 73-R6, August 1973.

3. Robertson, R. N., "Evaluation of High Intensity Sheeting for Overhead Highway Signs," Virginia Highway and Transportation Research Council, Report No. 75-R24, December 1974.

4. Robertson, R. N., and Shelor, J. D., "The Applicability of High Intensity Sheeting on Overhead Highway Signs," Virginia Highway and Transportation Research Council, Report No. 76-R3, August 1975.